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TITLE: PORTABLE RADIO FREQUENCY HYPERTHERMIA INSTRUMENTATION

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MASTER

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Portable Radio Frequency Hyperthermia Instrumentation[1,2]

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Abbreviations: rf = radio frequency; LED = light-emitting diode; MHz = megahertz (10^6 cycles per second)

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ABSTRACT--Portable radio frequency hyperthermia instrumentation has been constructed for application in the localized heating of human and animal tumors. Tissue temperature is regulated by electronic feedback techniques. Audible and visual monitoring of tissue temperature is provided.

INTRODUCTION

Localized rf current fields, applied by direct-contact electrodes(1) are appropriate for generating hyperthermia in a variety of locations. Lesions of the head and neck, particularly in the oral cavity, are often well-suited for this type of hyperthermia induction method. Alternately, there are instances where rf electrodes may be introduced through existing body orifices or by surgical intervention.

Regardless of the electrode configuration and temperature monitoring technique selected for a particular tumor location, instrumentation is required to produce the necessary levels of rf power. Ideally, this same instrument should be equipped with means for monitoring and controlling temperature levels in the tissue under treatment. Any instrument for use in the clinic should be straightforward to operate and reliable. With the increasing costs of medical care, an effort should be made during the design phase to minimize eventual manufacturing costs.

SYSTEM DESCRIPTION

We have developed portable rf instrumentation for the induction of hyperthermia into localized human tumors; design is similar, in part, to a veterinary instrument described earlier(2). This instrument has been designed with the primary goals of reliability and ease of operation by the physician. In addition, an effort was made to keep component and construction costs low. Less sophisticated veterinary instruments, based upon the earlier design, are currently marketed by several firms for a few hundred dollars. This recent instrument has more complex circuity, but can probably be constructed at a manufacturer's cost of less than $600 per unit.

Text-figure 1.--Block diagram of rf hyperthermia instrument. Unit delivers approximately 18 watts peak power into a 50-ohm tissue load at a frequency of 2 MHz. Temperature is regulated by electronic feedback control circuitry; temperature levels are monitored both by visual and audible sensors.

The heart of the instrument is an oscillator which will not operate until an appropriate (tissue) electrical load is placed in series with the external electrodes. This feature helps prevent burns which occur at poor electrode contacts and also protects the output rf transistor under open circuit conditions.

Unnecessary drain from the battery which powers the circuitry is also minimized by this type of oscillator design. If temperature is to be controlled, it is necessary to have the ability to rapidly modify the rf power levels in tissue to counteract unwanted temperature changes. This is accomplished by modulation of the oscillator rf power level. A temperature-error sensing circuit drives the modulator to maintain a condition where there is a very small difference between the thermistor temperature and a temperature command level which is manually set by the physician on a ten-turn front panel dial. The nominal range of this dial is 40 to 50°C. Another dial on the instrument panel allows the physician to adjust the maximum rf power available (0 to 100%) for the treatment of a particular tumor. Generally, more power is required for the larger and the more vascular tumors. The instrument is designed to automatically deliver more power to loads of lower electrical resistance (50 to 200 ohms), since this resistance range will represent larger tumors which require relatively more power than smaller tumors, where the electrical resistance may approach 1000 ohms. The actual resistance seen by the instrument is a function of electrode configuration (which is related to tissue volume heated) and tissue resistivity.

Text-figure 2.--Note that rf power output (above 50 ohms) decreases as tissue load resistance increases. This is appropriate since load resistance (for a constant electric resistivity) tends to be larger for smaller treated tissue volumes which require less power.

Tissue temperature is monitored by a thermistor which is approximately 2200 ohms at 25°C. Thermistors used in various applications are matched in response, thus eliminating the need to calibrate the instrument's temperature set-point control for each thermistor. If thermistors are interchanged, a given location on the ten-turn dial always corresponds to approximately the same thermistor temperature. Several of these instruments have been loaned to other users. In some applications(3), electrodes with integral matched thermistors have been utilized in experiments. In other cases, custom electrodes and thermistor mounts have been designed for special applications.

The physician is aided in the hyperthermia treatment by three indicators on the front panel of the instrument. An amber LED is energized whenever rf current is flowing through the tissue, so that the operator may know that proper electrode contact has been made.

It is, of course, crucial that the physician have information about the temperature of the tissue under treatment. While it will often be necessary to use separate temperature monitors in addition to the control thermistor used with this instrument, we have made the control temperature information available in two complementary forms. An audible temperature signal is provided via a miniature speaker on the front panel. The frequency of this signal is altered as the thermistor temperature changes, resulting in a rising pitch as the tissue is heated. In addition, this audible signal begins to "chirp" once each second when the preset temperature level is reached. This latter feature may be used in the fashion of a stopwatch to time the duration of short treatments.

A third indicator is a temperature-monitoring LED which has three states, i.e., green for temperature below the set-point, off for operation within about 1°C of the set-point temperature, and red for temperatures which exceed the set-point level. Generally, the operator should strive to use the lowest power level settings consistent with reaching the preset temperature for a particular tissue volume. If higher power levels are used than are necessary, temperature overshoot prior to temperature regulation may occur. In such cases, the temperature level LED will glow red for a transient period. In conservative treatment, the red glow of this indicator will not be seen.

Several of these instruments have been constructed, tested, and loaned to institutions for use in hyperthermia programs. Complete construction information is available upon written request to the authors.

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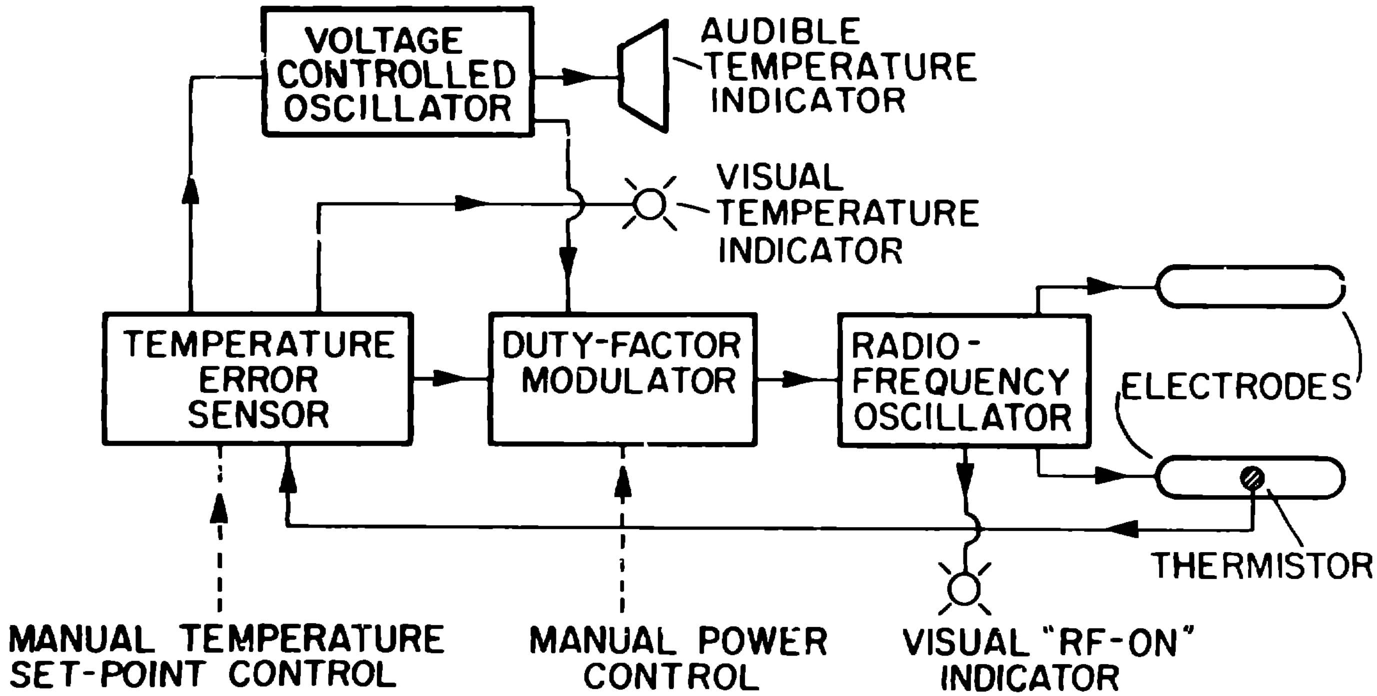
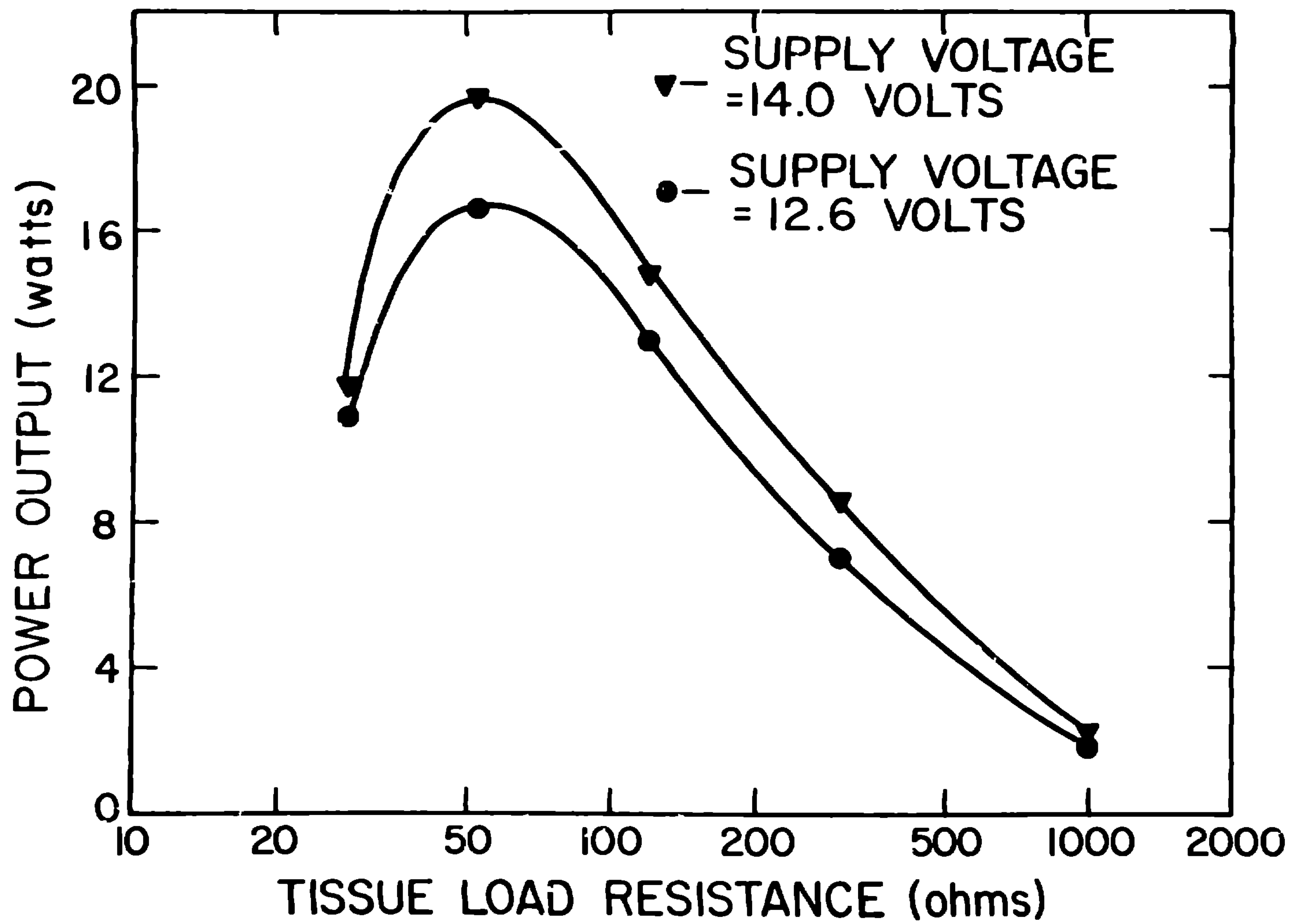

VOLTAGE CONTROLLED OSCILLATOR
AUDIBLE TEMPERATURE INDICATOR
VISUAL TEMPERATURE INDICATOR
TEMPERATURE ERROR SENSOR
DUTY-FACTOR MODULATOR
RADIO-FREQUENCY OSCILLATOR
ELECTRODES
THERMISTOR
MANUAL TEMPERATURE SET-POINT CONTROL
MANUAL POWER CONTROL
VISUAL "RF-ON" INDICATOR



SUPPLY VOLTAGE =14.0 VOLTS
SUPPLY VOLTAGE = 12.6 VOLTS
POWER OUTPUT (watts)
0
4
8
12
16
20
10
20
50
100
200
500
1000
2000
TISSUE LOAD RESISTANCE (ohms)